Simulation of the LHCb electromagnetic calorimeter response with GEANT4

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Simulation of the LHCb Electromagnetic Calorimeter response with GEANT4

XI International Conference
on Calorimetry in High Energy Physics
Calor 2004

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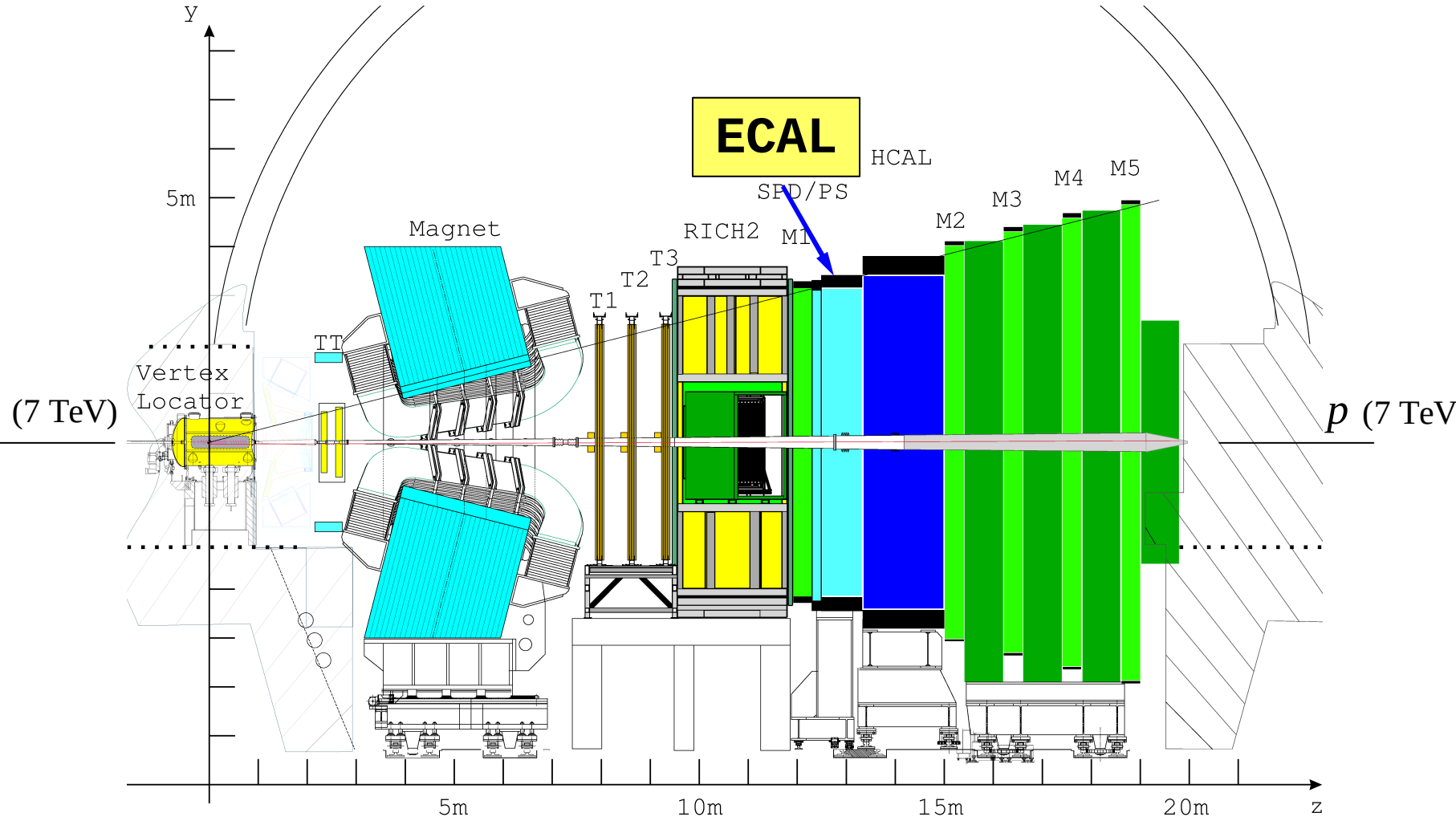
Outline

- Principles and setup of the LHCb ECAL Simulation
- Specific LHCb ECAL Implementations
- Comparison with test beam data

The LHCb Detector



Precision *B* physics experiment at LHC

The LHCb Electromagnetic Calorimeter (ECAL)

- Lead – Scintillator shashlik detector
  - Light collected by WLS fibers
  - Readout by PMT at the back of the detector
- Provides fast information for trigger (high p_T γ, e, π^0)
- Reconstruction of B hadrons with neutral final states ($B^0 \to K^{*0}\gamma$, $B^0 \to \pi^+\pi^-\pi^0$,...)
- Identification of $e^{\pm}$ (for reconstruction, tagging, ...)

ECAL Simulation with GEANT4

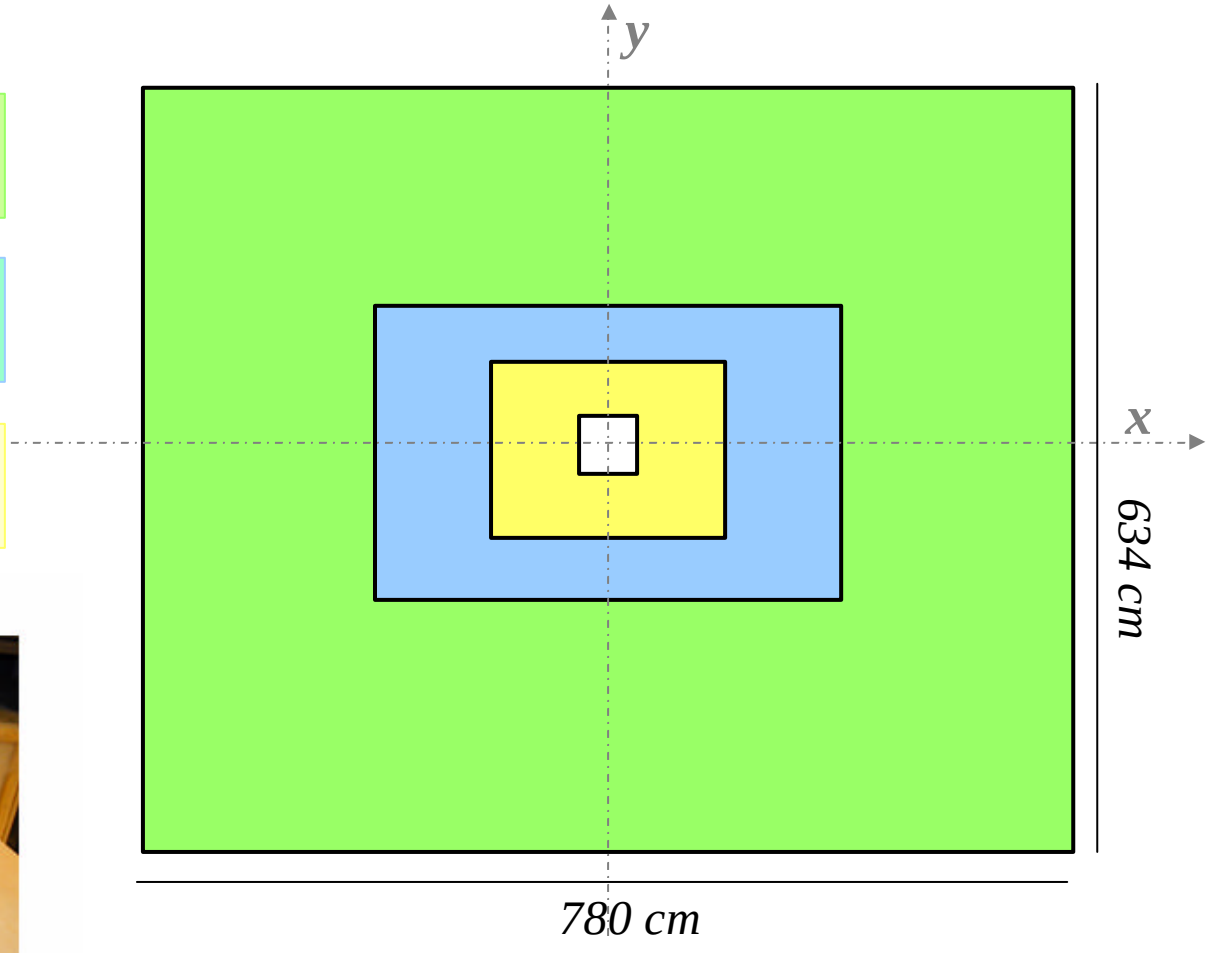
- Simulation of detector response is based on GEANT4 and ECAL simulation is integrated into the entire LHCb simulation software.
- General framework:
  - Primary particles (produced by Pythia for the p-p collisions, EvtGen for B decays and from background) are given to GEANT4 for processing.
  - GEANT4 is set up with:
    - specific LHCb geometry and material description
    - specific actions to simulate ECAL behaviour
- Execution speed is an issue

Geometry Setup

Outer ECAL: 2688 cells
(12 cm × 12 cm)

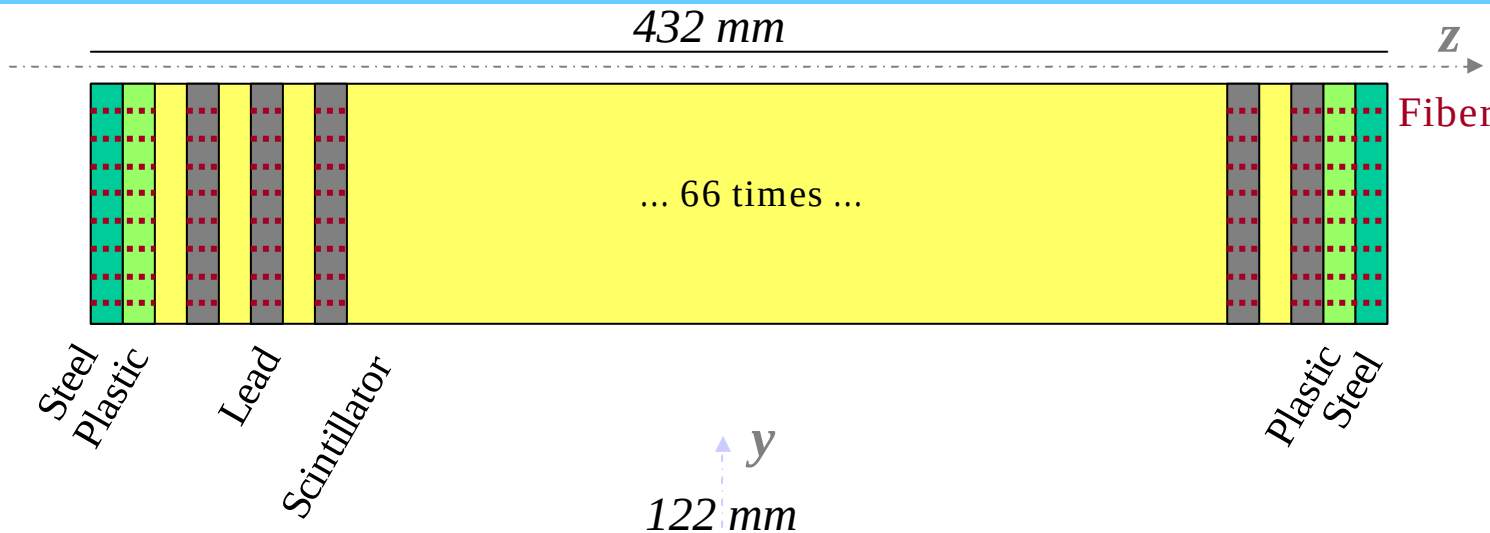
Middle ECAL: 1792 cells
(6 cm × 6 cm)

Inner ECAL: 1584 cells
(4 cm × 4 cm)

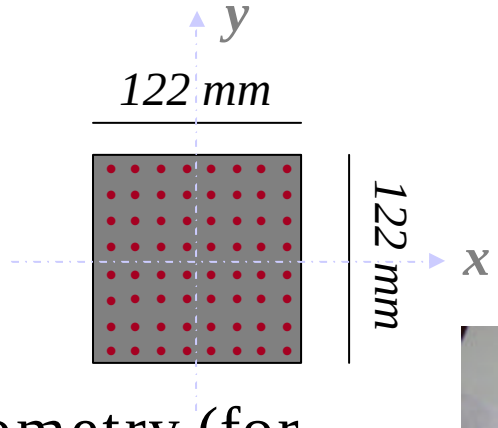


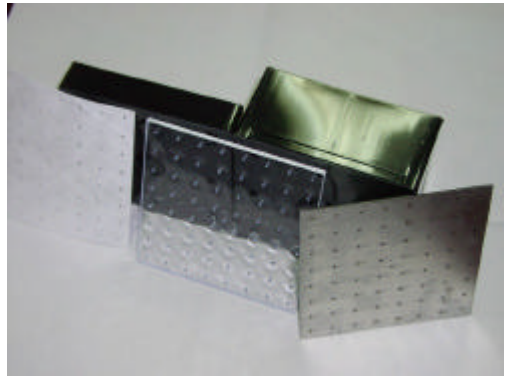
ECAL Outer Module

• Stack:



• Lead Tile:



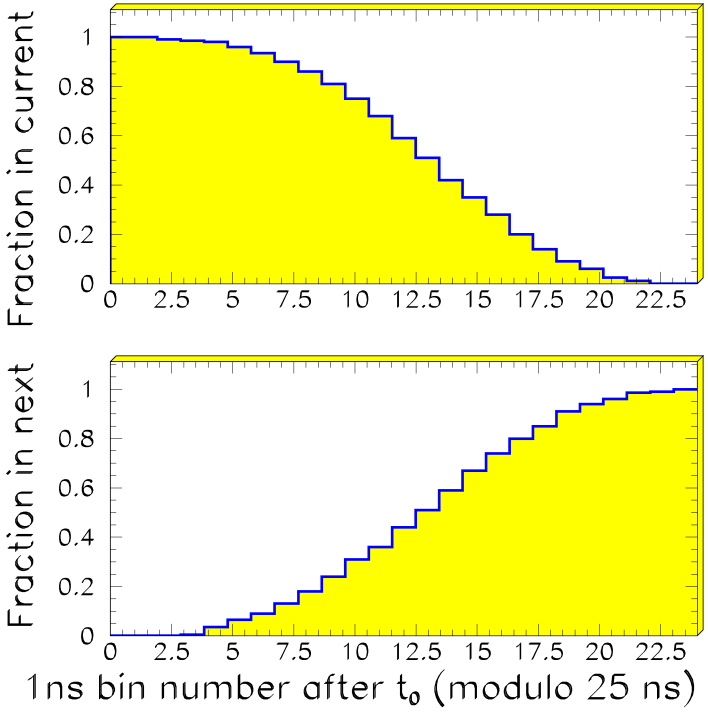


• Detailed and optimized geometry (for example, no fiber in Scintillator, but they are the same material)

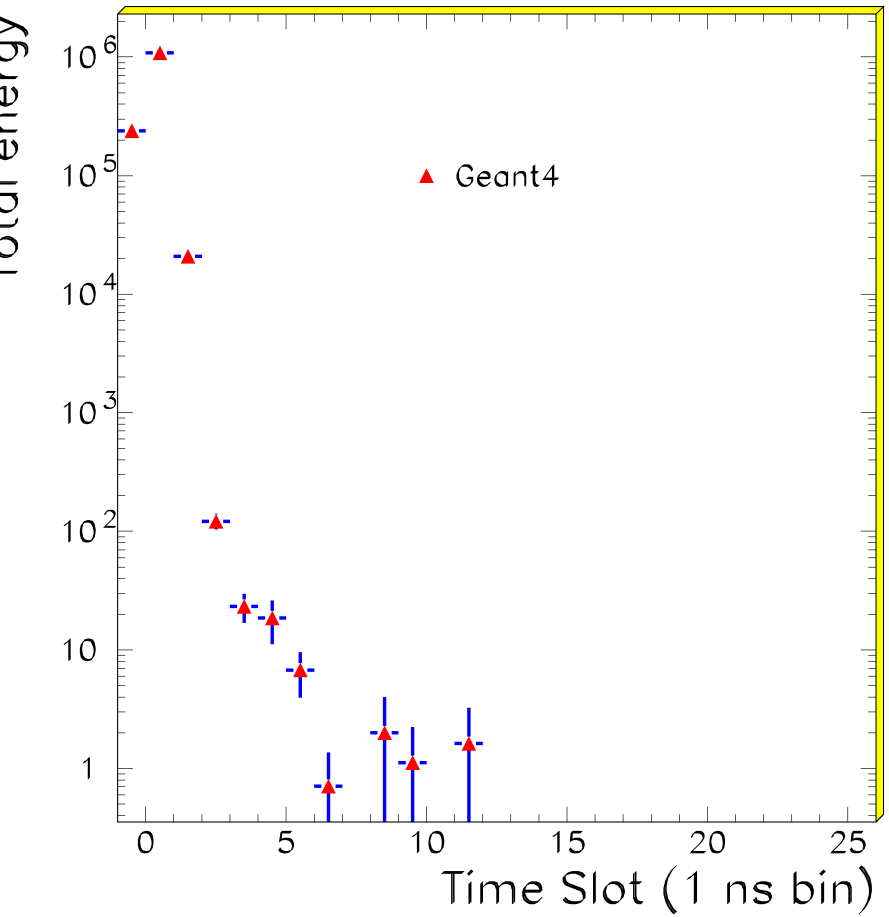
• Active material is Scintillator Tile

Timing (1)

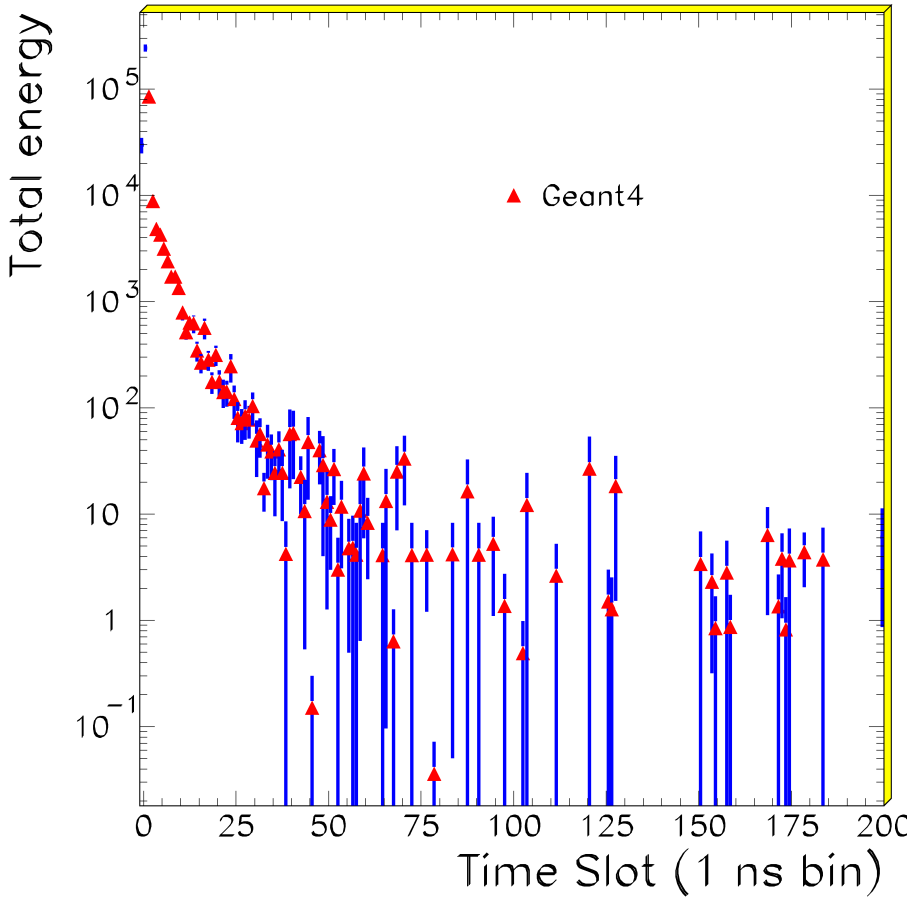
- Specific ECAL implementation
- Share each energy deposition in ***two consecutive 25 ns time bins***, according to test beam measurements.
- Simulates signal integration by electronics chain.
- t_0 = time of arrival of photons at the *z* position of the maximum of the shower *ie* 11 cm after ECAL front surface.



Timing (2)



photons



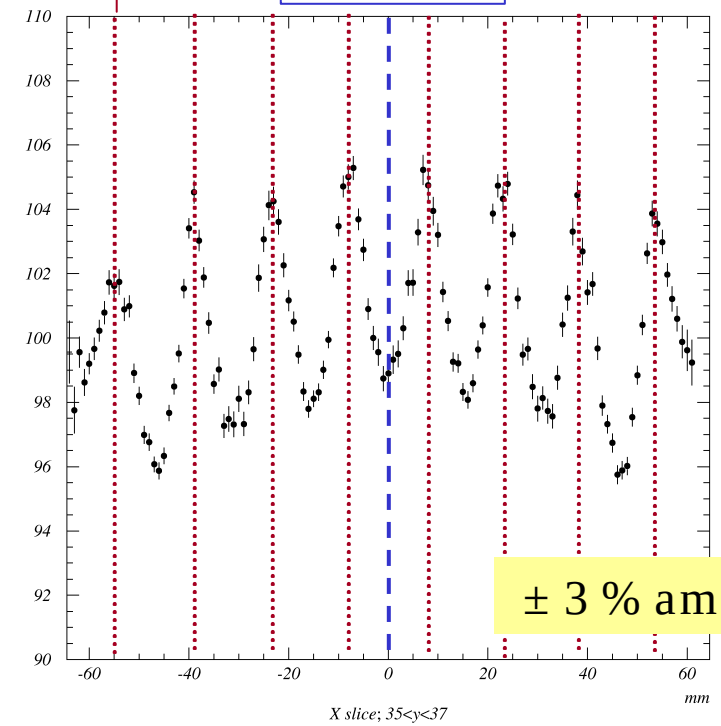
pions

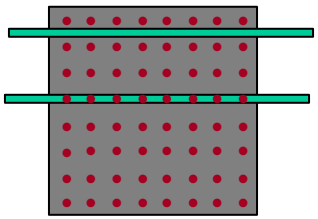
Non Uniformities – Muon Test Beam

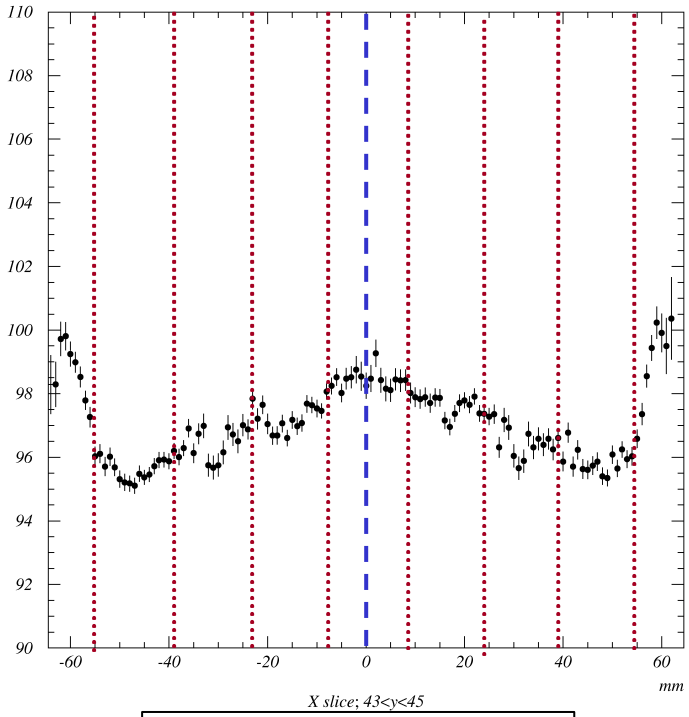
Scan with muons perpendicular to ECAL cell

Fiber positions

Cell Center







± 3 % amplitude

Slice in a fiber row

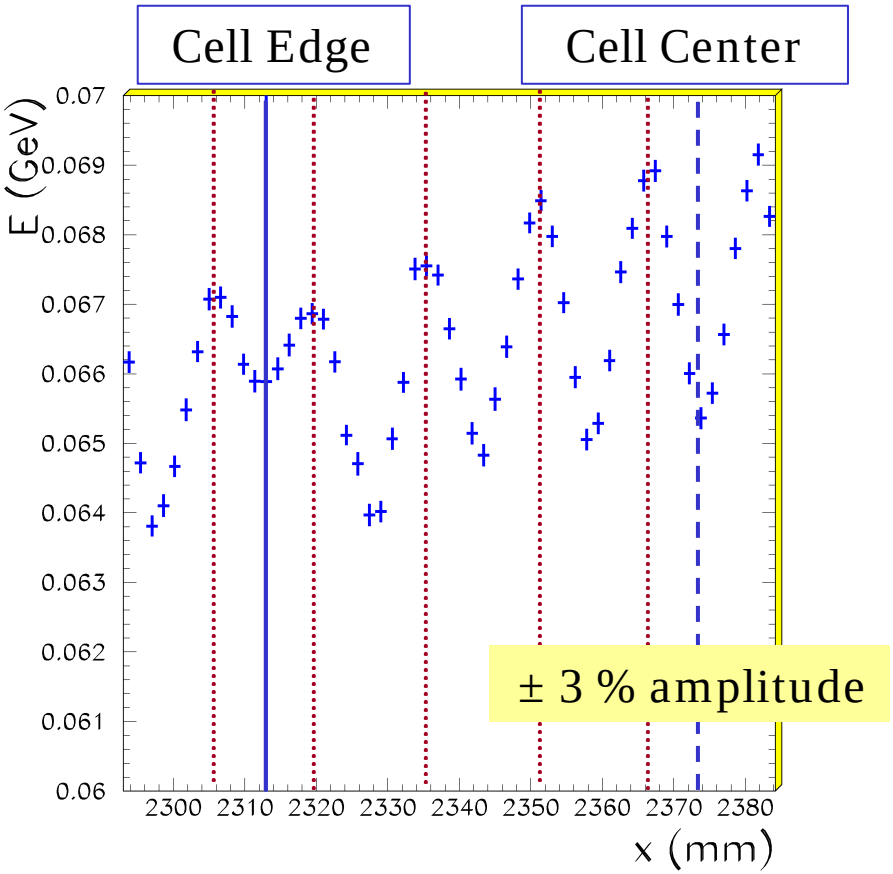
Slice between 2 fiber rows

Non Uniformities – Simulation

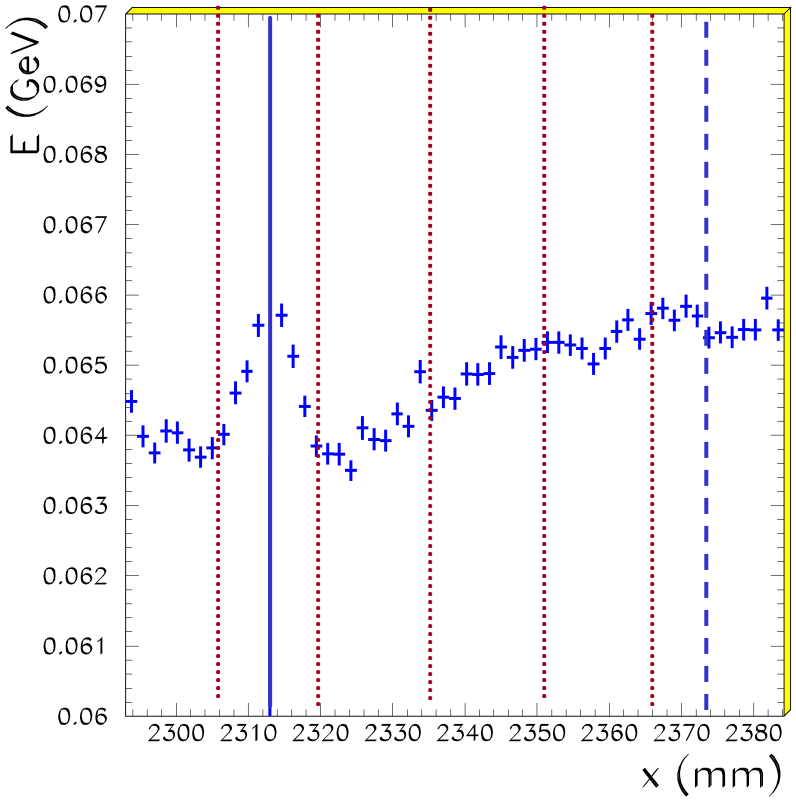
- 3 different components:
  - Local Non Uniformity:
    - $A \times (1-\cos 2\pi(x-x_0)/d) \times (1-\cos 2\pi(y-y_0)/d)$
    - (x_0, y_0) = center of the cell
    - d = distance between fibers
  - Global Non Uniformity:
    - $B \times (x-x_0+L/2)^2 \times (y-y_0+L/2)^2$
    - L = cell size
  - Reflection on the edges of the tile (for one side):
    - $C \times \exp(-|x-x_0+L/2|/D)$

Non Uniformities – Muon Simulation

Scan with muons perpendicular to ECAL cell



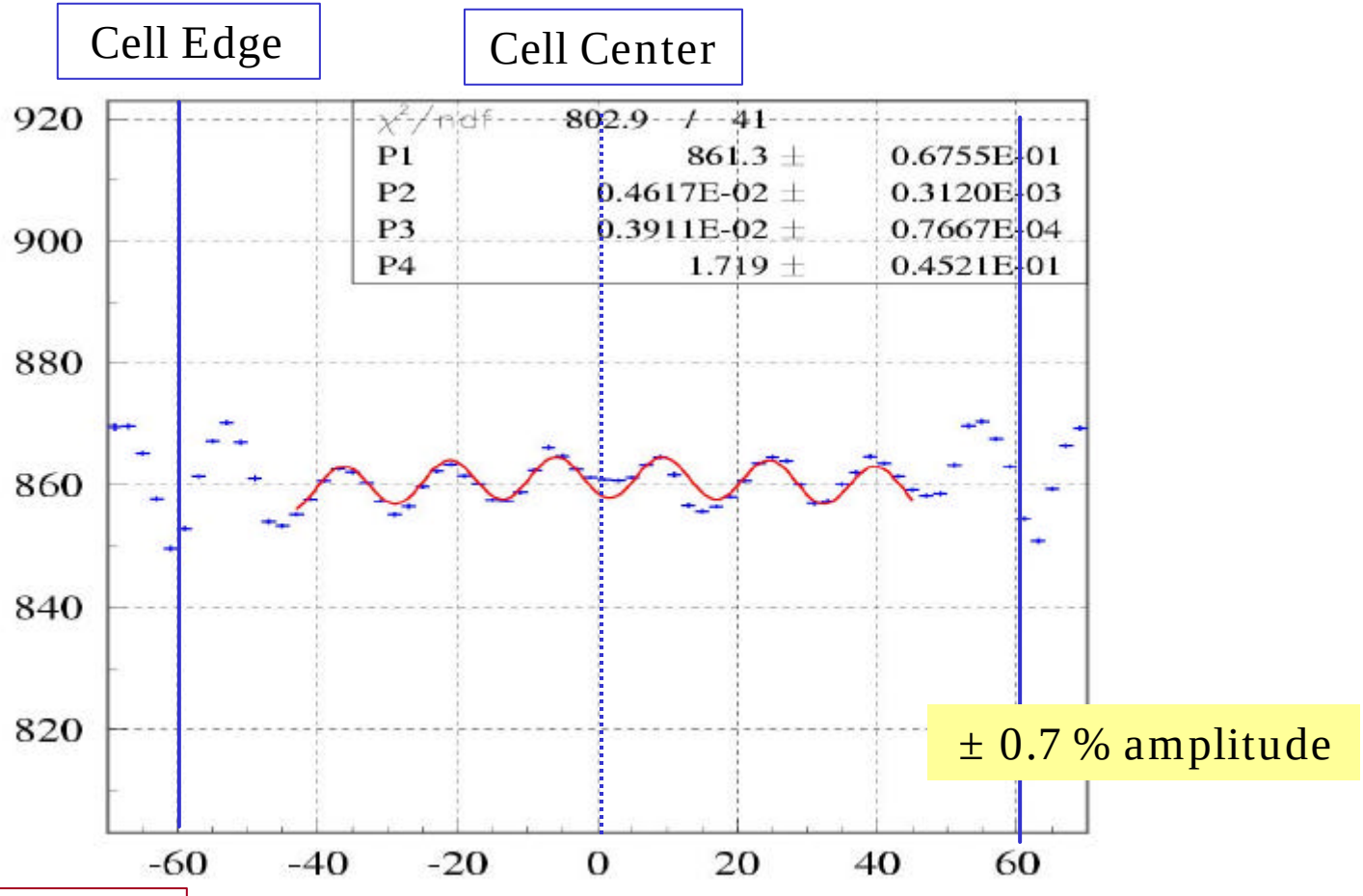
Slice in a fiber row



Slice between 2 fiber rows

Non Uniformities – Electron Test Beam

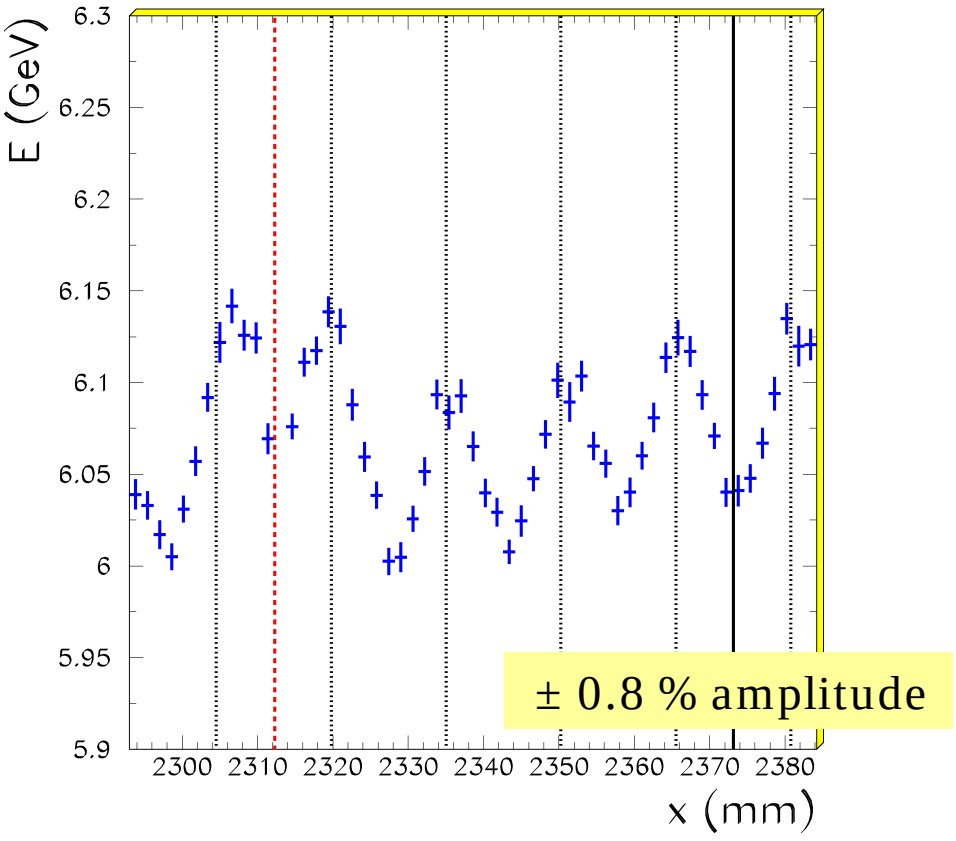
Scan with 50 GeV electrons perpendicular to ECAL cell



Preliminary results

Non Uniformities – Electron Simulation

Scan with 50 GeV electrons perpendicular to ECAL cell

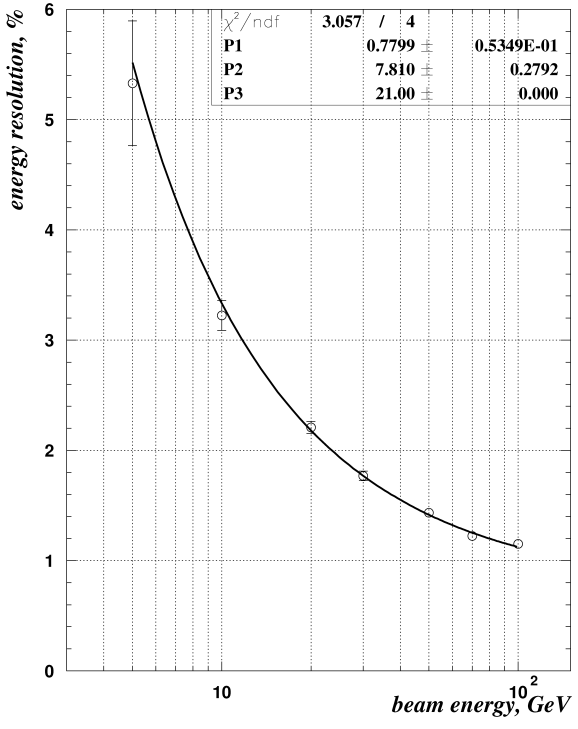


- Preliminary results
- Parameters that reproduce muon test beam data do not reproduce electron test beam data (factor 2 between them)
- This will be studied in more details (including other cell size of ECAL) with test beam this summer

Resolution – Test Beam

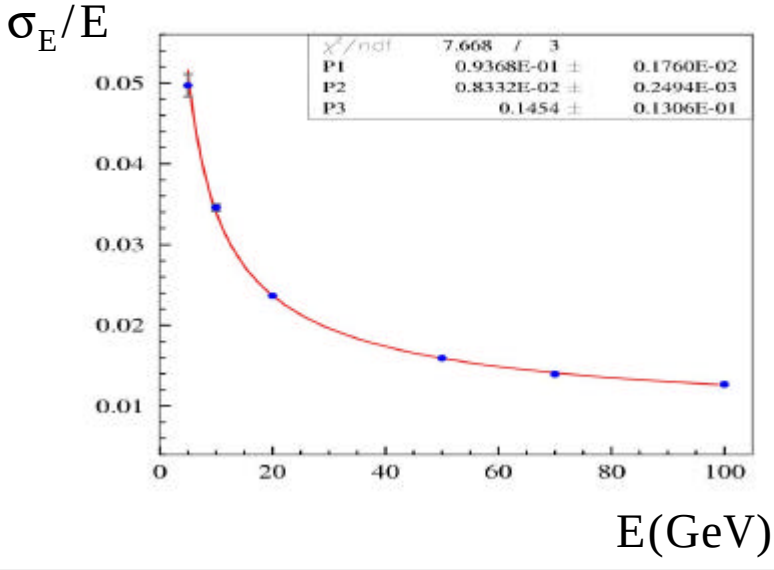
Electrons perpendicular to the module

Middle Module



$\sigma_E/E = (7.8 \pm 0.3)\%/E^{0.5} \oplus (0.78 \pm 0.05) \%$

Outer Module

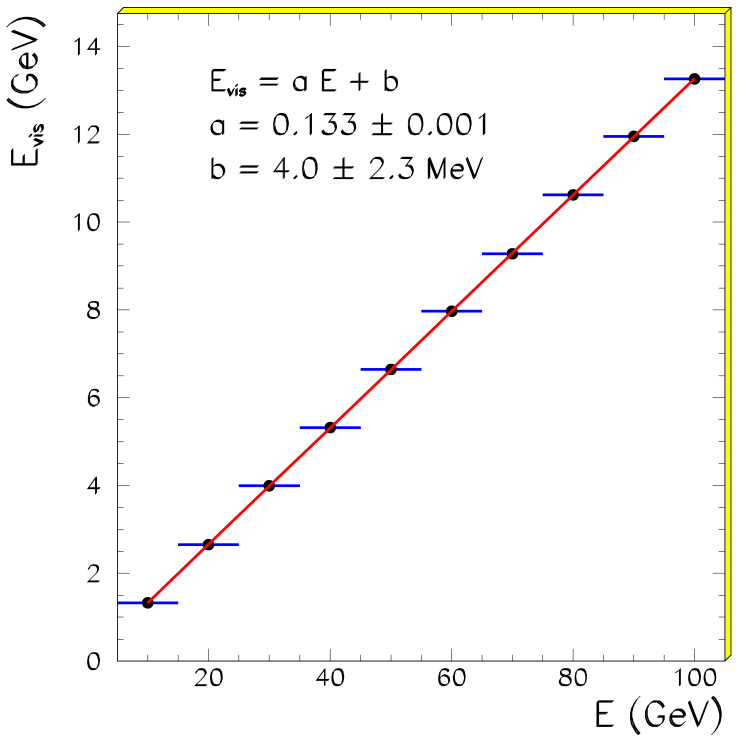


$\sigma_E/E = (9.4 \pm 0.4)\%/E^{0.5} \oplus (0.83 \pm 0.02) \%$

Resolution – Simulation

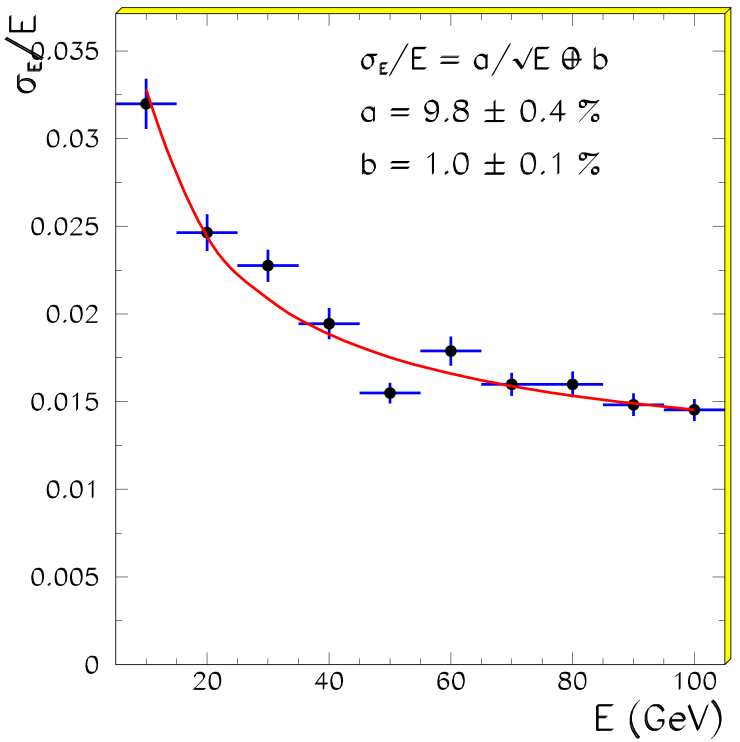
Electrons perpendicular to one Outer Module

Linearity



Active / Total = 7.5 ± 0.1

Resolution



$\sigma_E/E = (9.8 \pm 0.4)\%/E^{0.5} \oplus (1.0 \pm 0.1) \%$

Conclusions

• LHCb simulation software contains a realistic simulation of ECAL detector.

• Timing and non uniformities are taken into account in the simulation.

• For non uniformities, more detailed studies with new test beam data will be performed in the near future.